Program

There are three broad themes, corresponding to “pillars of the standard model”. These pillars are:

The laws of physics: The basic theoretical frameworks that we rely on for building cosmological models (includes GR, standard model of particle physics) **Foundational assumptions:** Basic assumptions that we make when constructing theories and interpreting observations (includes homogeneity, isotropy, Big Bang, inflation…) **Constituents of the Universe:** What the Universe is made of, and how it behaves (includes dark energy/vacuum energy, dark matter, neutrinos…)

Each session is approximately 3 hours long punctuated by a tea break. In each section, we seek to go beyond the standard model by modifying or replacing these pillars in some way. For example, modified gravity theories replace a law of physics, GR; models of dark energy add a new fluid to the content of the Universe; and so on.

Wed. AM	**Intro: Successes and failures of LCDM** (chair: Per Lilje)
8:30	(10m) Introduction/aims of the conference *LOC and SOC*
	(10m) Conference opening by the Dean of the Faculty of Mathematics and Natural Sciences at University of Oslo *Prof. Morten Dæhlen*
8:50	(45m) LCDM: Successes and status *G. Efstathiou*
9:45	(45m) LCDM: Theoretical problems Discussion based on votes *R. Durrer*
10:40	**(20m) Break**
11:00	(45m) Anomalies *H. Peiris*

Wed. noon

12:00-16:00 **Lunch (The Gallery) and long break**

Wed. PM **Flash talks and discussions** (chair: Licia Verde)

from 15:15 Put up the posters for the poster session

16:00 (60m) Poster talks (12x5min), Cui, Quintin, Herranen, Pieroni, Arnold, Pereira, Thomas, Bentivegna, Candlish, Verde/Heavens, Sownak

17:00 **(40m) Break for poster viewing**

17:40 (60m) Discussion groups (5x parallel)

Group 1 (Board Room 1, Lavinia Heisenberg/Jonas Enander/Ippocratis Saltas): Why not just Λ?

Group 2 (Board Room 3, Ignacy Sawicki/Enea Di Dio/Bin Hu): What statements about ΛCDM can be made in a model independent way?

Group 3 (Board Room 5, Jose Beltran Jiminez/Tessa Baker/Claudio Llinares): Developing MG theories: Theoretical directions & motivations / role of simulations

Group 4 (Board Room 7, Matteo Viel/Marcel Pawlowski/Till Sawala): Small-scale structure: Which problems are real? Which solutions are viable?

Group 5 (Jacob Vaage Room, Fabio Finelli/Daniele Steer/Sebastien Clesse): Can we know it was inflation? Fundamental limits to observations

18:40 (30m) Follow-up summary from discussion group leads

19:10 **End of day and dinner (The Gallery)**

Thu. AM **Overview talks: Physical Laws and Dark Energy** (chair: Yashar Akrami)

8:30 (30m) Gravity in Cosmology

P. G. Ferreira

9:15 (30m) Cosmology and the Cosmological Constant Problem: A Bad Cop Wrapped in a Wet Blanket Standing in a Cold Shower

C. Burgess

10:00 (30m) Constituents: Simulating the Universe

R. Teyssier

10:40 **(20m) Break**

11:00 (30m) Constituents: Observing dark energy with many surveys: Interplay

O. Lahav

11:45 (30m) Constituents: Observing dark energy with galaxy surveys

B. Reid

Thu. Noon

12:30-16:00 Lunch (The Gallery) and long break

Thu. PM **Flash talks and discussions** (chair: Marit Sandstad)

16:00 (30m) Constituents: What happened in the early universe?

S. Mukhanov

16:40 (30m) Flash talks A (Saga Hall, Marit Sandstad): Asymmetries

Lavinto: A supervoid cannot explain the Cold Spot

Quartin: On the significance of power asymmetries in CMB data at all scales

(30m) Flash talks B (Board Room 5, Claudio Llinares): Modified gravity

Famaey: The essentials of MOND

Pasechnik: Dark Energy from gravity-mediated interactions in QCD vacuum

17:10 (20m) Break

17:30 (60m) Discussion groups (5x parallel)

Group 1 (Board Room 1, Mikael von Strauss/Roman Pasechnik/Yashar Akrami): Cosmological constant problem: Disaster, or inconsequential? Possible ways out?

Group 2 (Board Room 3 Edvard Mortsell/Vincenzo Salzano/Ismael Tereno): DE model selection and parametrisations: What do we expect to learn about DE from forthcoming data?

Group 3 (Board Room 5, Julian Adamek/Johannes Noller/Adam Solomon): Alternatives to ΛCDM: What works and what doesn't?

Group 4 (Board Room 7, Eloisa Bentivegna/Francisco Villaescusa-Navarro/Hans Winther): Are cosmological simulations fit for purpose?

Group 5 (Jacob Vaage Room, Sigbjorn Hervik/Jussi-Pekka Väliviita/Massimiliano Rinaldi): The inflationary paradigm: More problems than solutions?

18:30 (30m) Follow-up summary from discussion group leads

19:00 End of day and conference dinner (The Gallery)

Fri. AM	**Overview talks: Foundational Assumptions and New Particles** (chair: Phil Bull)
8:30	(30m) Testing foundational assumptions of LCDM *R. Maartens*
9:15	(30m) An Uncooperative Universe: Large Scale Anomalies in the CMB *G. Starkman*
10:00	**(20m) Break**
10:20	(30m) Constituents: New particles and structure formation *C. Boehm*
11:00	(60m) Flash talks: Structures *Pawlowski: ΛCDM's most severe small-scale problem: The ubiquity of co-orbiting satellite galaxy planes* *Nadathur: Large-scale structures and anomalies in the CMB* *Adamek: N-body Simulation meets General Relativity* *Schewtschenko: DM goes social: Structure formation in the presence of interactions between DM and radiation* *Villa: Cosmology beyond the linear and Newtonian approximations*
Fri. Noon	
12:00-16:00	**Lunch (The Gallery) and long break**
Fri. PM	**Flash talks and discussions** (chair: Signe Riemer-Sørensen)
16:00	(30m) Flash talks A (Saga Hall, Signe Riemer-Sørensen): Parameters *Mueller: Cross-correlating CMB and LSS: Cosmology with the kinetic SZ effect* *Sawala: Bent By Baryons: Local Tests for Dark Matter* *Di Dio: Cosmological Parameter Estimation with Galaxy Number Counts* (30m) Flash talks B (Board Room 5, Amir Hammami): Dark Energy *Javanmardi: Probing isotropy of cosmic acceleration* *Romano: Non perturbative effects of primordial curvature perturbations on the apparent value of a cosmological constant*
16:30	(60m) Discussion groups (5x parallel) *Group 1 (Board Room 1, Licia Verde/Seshadri Nadathur/Phil Bull): Stress-testing ΛCDM: Are we trying hard enough to falsify it?* *Group 2 (Board Room 3, Stefano Camera/Jeremy Sakstein): Observing*

MG / Roadmap to distinguishing DE from MG

Group 3 (Board Room 5, Ofer Lahav/Miguel Quartin/Emilio Bellini): Novel observables: What next to push cosmology forward?

Group 4 (Board Room 7, Jonathan Davis/Douglas Spolyar/Signe Riemer-Sørensen): DM detection: Does it matter what DM is made of? What if it's never detected?

Group 5 (Jacob Vaage Room, Thiago Pereira/Sigurd Naess/Angelo Ricciardone): Anomalies: Confirming old ones and finding new ones

17:30 **(20m) Break**

17:50 (30m) Follow-up summary from discussion group leads

18:30 (30m) Flash talks A (Saga Hall, Signe Riemer-Sørensen): New particles

Villaescusa-Navarro: The impact of massive neutrinos on the large scale structure of the Universe

Davis: Dark Matter vs. Neutrinos: Using timing-information to improve the sensitivity of Direct Detection experiments

(30m) Flash talks B (Board Room 5, Max Grönke): Inflation

Finelli: Planck constraints on inflation

Beltran Jimenez: Inflation in minimal extension of Born-Infeld gravity

19:00 **End of day and dinner (The Gallery)**

Sat. AM **Summary talks: Where do we go from here?** (chair: David Mota)

9:00 (30m) Radical solutions (in the spirit of Hoyle)

J. Magueijo

9:45 (15m) Poll

10:00 (60m) Summary and directions: What next?

A. Heavens

11:15 **End of conference and lunch (The Gallery)**

Abstracts

G. Efstathiou: LCDM: Successes and status (45m)

The LCDM model has survived more than a decade of —increasingly stringent— precision

tests, which culminated, recently with the announcement of the latest results from the Planck satellite. I will present a summary of the Planck 2014 cosmological results highlighting the successes of the LCDM model. The Planck data impose tight limits on possible new physics beyond the LCDM model.

R. Durrer: LCDM: Theoretical problems (45m)

Discussion based on pre-conference survey

H. Peiris: LCDM: Anomalies (45m)

Anomaly detection drives scientific discovery - it is correlated with the cutting edge of the research frontier, and thus inevitably involves small signal-to-noise. In astronomy, the prevalence of systematics -- both "known unknowns" and "unknown unknowns" -- combined with increasingly large datasets, the prevalence of ad hoc estimators for anomaly detection, and the "look elsewhere" effect, can lead to spurious false detections. I will argue that anomaly detection leading to discoveries of new (astro)physics needs a combination of physical understanding, careful experimental design to avoid confirmation bias, and self-consistent statistical methods. I will illustrate these points with several concrete examples from cosmology.

P. G. Ferreira: Gravity in Cosmology (30m)

I will discuss the possibility that we might constrain gravity- Newtonian and General Relativistic- with cosmological observations. Such constraints should be competitive and complementary with solar system and pulsar constraints. I will also point out the real problems we face in achieving such constraints.

C. Burgess: Cosmology and the Cosmological Constant Problem: A Bad Cop Wrapped in a Wet Blanket Standing in a Cold Shower (30m)

We live at a time of contradictory messages about how successfully we understand gravity. General Relativity seems to work well in the Earth’s immediate neighborhood, but arguments abound that it needs modification at very small and/or very large distances. This talk tries to put this discussion into the broader context of similar situations in other areas of physics, and summarizes some of the lessons, which our good understanding of gravity in the solar system has for proponents for its modification over very long and very short distances. The main message is mixed: On one hand cosmology seems to like features (like light scalars and small vacuum energies) that are not generic to the long-wavelength limit of fundamental theories, and this is a crucial clue that would be silly to ignore. On the other hand, although some ways are known to contrive light scalars (and so among which we can seek explanations for observations), so far none are known that all agree could incorporate small vacuum energies (even in principle), making this a clue that is very difficult to use (at least until a convincing example is found).

R. Teyssier: Constituents: Simulating the Universe (30m)

Computer simulations play an important role in predicting the properties of the mass

distribution in the Lambda CDM scenario of structure formation. I will address the following questions: How reliable are these predictions using present-day computer and N body codes ? Is the extreme level of accuracy required by present and future surveys reached? What is the effect of baryonic physics? What are the challenges in simulating baryonic physics and galaxy formation? How well do we understand these effects? Do we need to understand these effects? I will finally discuss the challenges of simulating models beyond standard gravity, and the challenges of detecting their signature.

O. Lahav: Constituents: Observing dark energy with many surveys: Interplay (30m)

B. Reid: Constituents: Observing dark energy with galaxy surveys (30m)

S. Mukhanov: Constituents: What happened in the early universe? (30m)

R. Maartens: Testing foundational assumptions of LCDM (30m)

The LCDM model is built on a large inter-connecting set of physical assumptions. Perhaps the most basic assumption is the Cosmological Principle. How confident can we be that the Universe is well described by a Friedmann model on large scales? I will describe some of the tests that have been devised to probe this. I will also discuss the role of the CP in tests of dark energy and gravity. The next key assumption is that GR describes the Universe. Others will investigate alternatives to GR as a theory of gravity. I will instead highlight the fact that sometimes we forget to apply GR consistently and thoroughly - for example, when assuming that a Newtonian approximation is always sufficient for analysing galaxy survey data. I will explore some of the problems and consequences of applying GR consistently in LCDM.

G. Starkman: An Uncooperative Universe: Large Scale Anomalies in the CMB (30m)

The Cosmic Microwave Background Radiation is our most important source of information about the early universe. Many of its features are in good agreement with the predictions of the so-called standard model of cosmology -- the Lambda Cold Dark Matter Inflationary Big Bang Theory. However, the large-angle fluctuations of the microwave background are uncooperative with "the program" -- they continue to exhibit several statistically significant anomalies. On the one hand, if we look at the whole sky the lowest multipoles seem to be correlated both with each other and with the geometry of the solar system. On the other hand, when we look just at the part of the sky that we most trust – the part outside the galactic plane - there is a dramatic lack of large angle correlations. So much so that it challenges basic predictions of the standard model. We will discuss these anomalies and how we might test whether they reflect profound underlying physics, or just statistical flukes.

C. Boehm: Constituents: New particles and structure formation (30m)

J. Magueijo: Radical solutions (in the spirit of Hoyle) (30m)

What if the basic assumptions we have made in our models of the universe are completely

wrong? In this talk I step back and examine how cosmology could be radically different and this explain the unsolved problems of the standard model.

A. Heavens: Summary and directions: What next? (60m)

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